Hydrogeologic Framework of the Floridan Aquifer System in Florida and in Parts of Georgia, Alabama, and South Carolina

By JAMES A. MILLER

REGIONAL AQUIFER-SYSTEM ANALYSIS

U.S. GEOLOGICAL SURVEY PROFESSIONAL PAPER 1403–B

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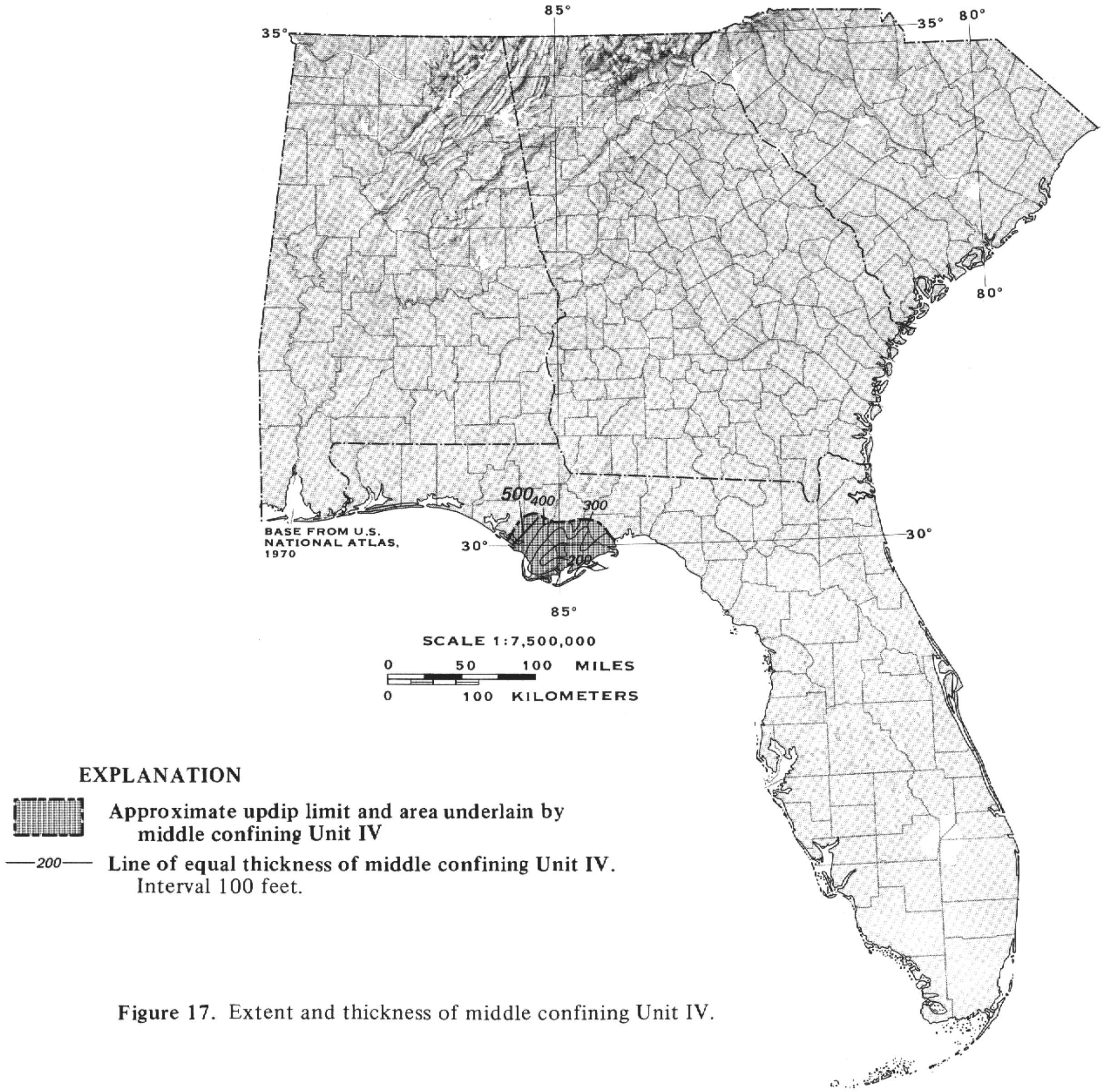


Figure 17. Extent and thickness of middle confining Unit IV.

these places, the rocks equivalent to unit VII are not gypsiferous, possibly because a more vigorous flow system has removed the gypsum by dissolution. On the basis of its lithology, unit VII is thought to be an effective confining unit, but hydraulic head data to quantify its effectiveness are lacking.

Lower Floridan Aquifer

All beds in the Floridan aquifer system that lie below the base of one of the middle confining units and above the base of the aquifer system are included in the Lower Floridan aquifer. Because it is deeply buried and in many places contains poor-quality water, the Lower Floridan has not been intensively drilled or tested, and its hydraulic character is therefore not well known. Scattered hydraulic data show large to small head differences between the Upper and Lower Floridan aquifers. The magnitude of these differences is directly related to the character of the middle confining unit that separates the aquifers; greater differences are found where the confining unit is virtually nonleaky. Ground-water flow in the Lower Floridan aquifer is sluggish except in those places where it is directly connected to the Upper Floridan aquifer. In the regional model discussed by Bush and Johnston (1985), active regional ground-water flow is thought to

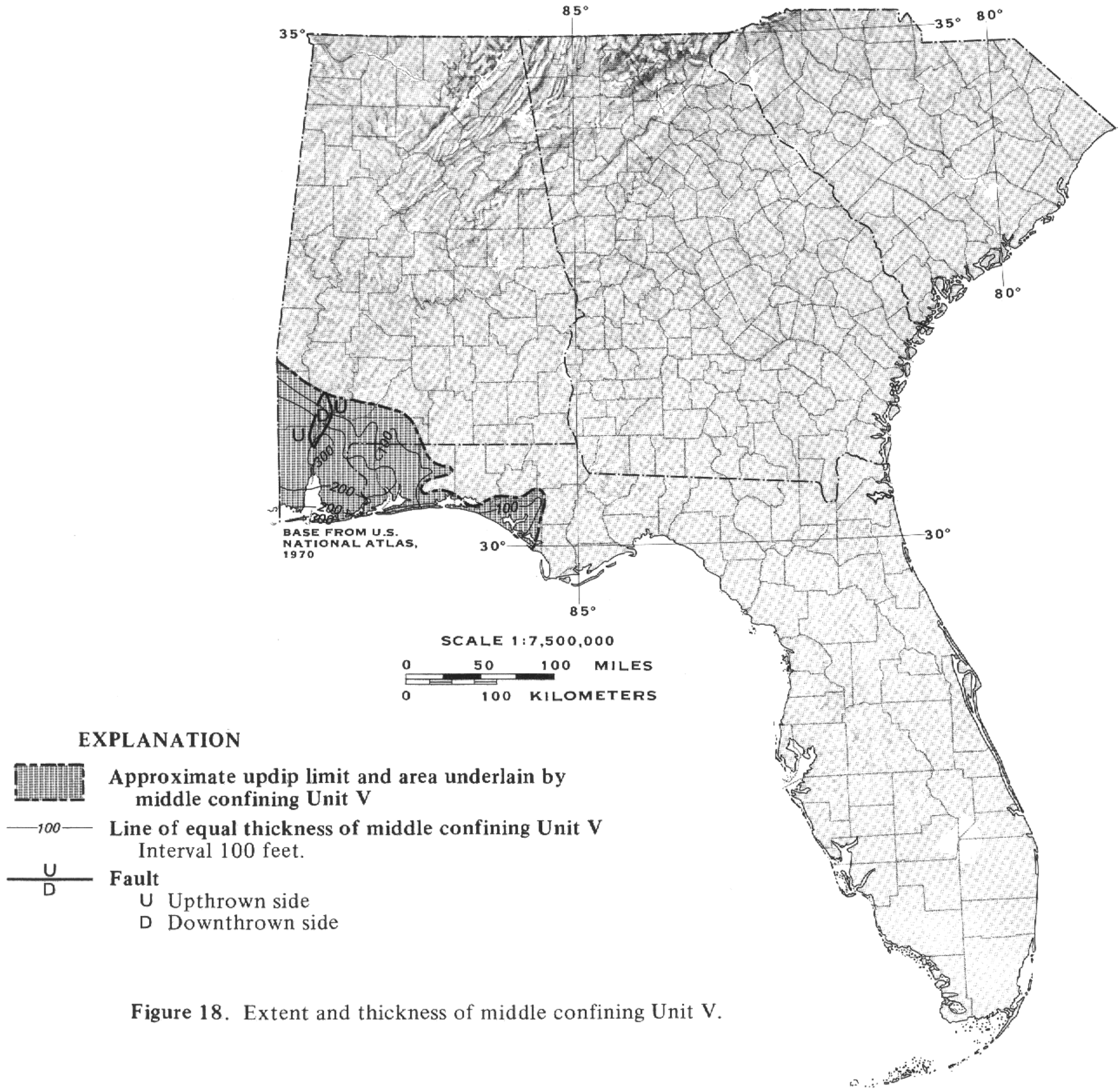
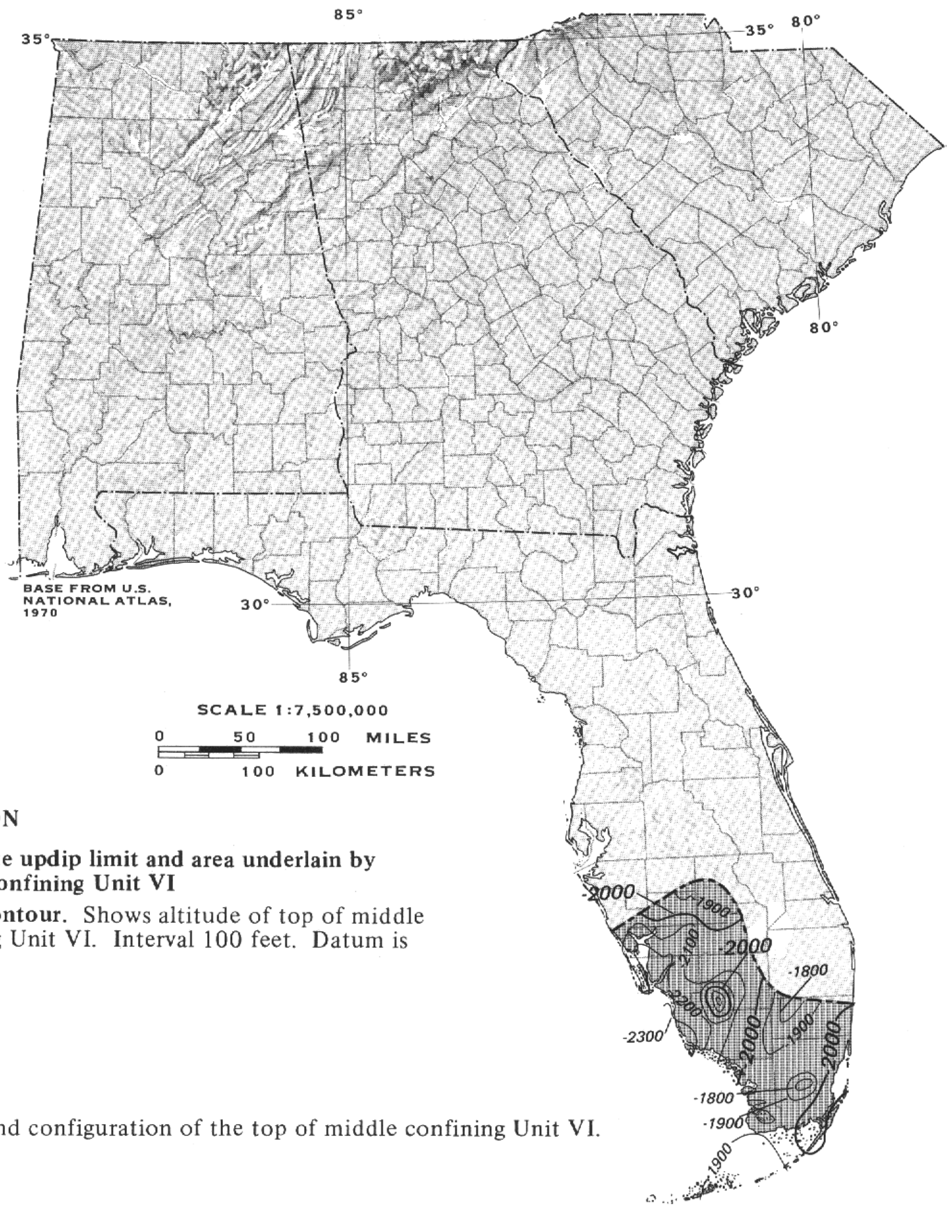


Figure 18. Extent and thickness of middle confining Unit V.

occur in the Lower Floridan aquifer. However, where the Lower Floridan lies below confining beds that are practically nonleaky, it is isolated from the Upper Floridan; and, throughout all of the area treated in the subregional model of Ryder (1985) and part of the area treated by Krause and Randolph (1985), the Lower Floridan is not considered part of the freshwater flow system.

The altitude of the top of the Lower Floridan aquifer is shown on plate 31. Because the top of the Lower Floridan is defined as the base of the highest subregional middle confining unit (units I - III) and because the stratigraphic positions, altitudes, and thicknesses of the confining units vary considerably, the contours shown on plate 31 are drawn on several different horizons. The contact lines shown on the plate mark the approximate limits of the different middle confining units. Where the confining units overlap, as they do in central and southern Florida, the base of the higher unit is contoured, and the extent of the overlap is shown by overlapping contact lines. The Lower Floridan aquifer is not mapped where no middle confining unit exists. In these places, the Lower Floridan merges with and is mapped as part of the Upper Floridan aquifer. The thickness of the Lower Floridan aquifer is mapped on plate 32.

The character of the Lower Floridan aquifer varies from simple (as it is in much of panhandle Florida, where it consists of a thin, fairly uniform sequence of upper Eocene limestone (fig. 9)), to highly complex (as



EXPLANATION

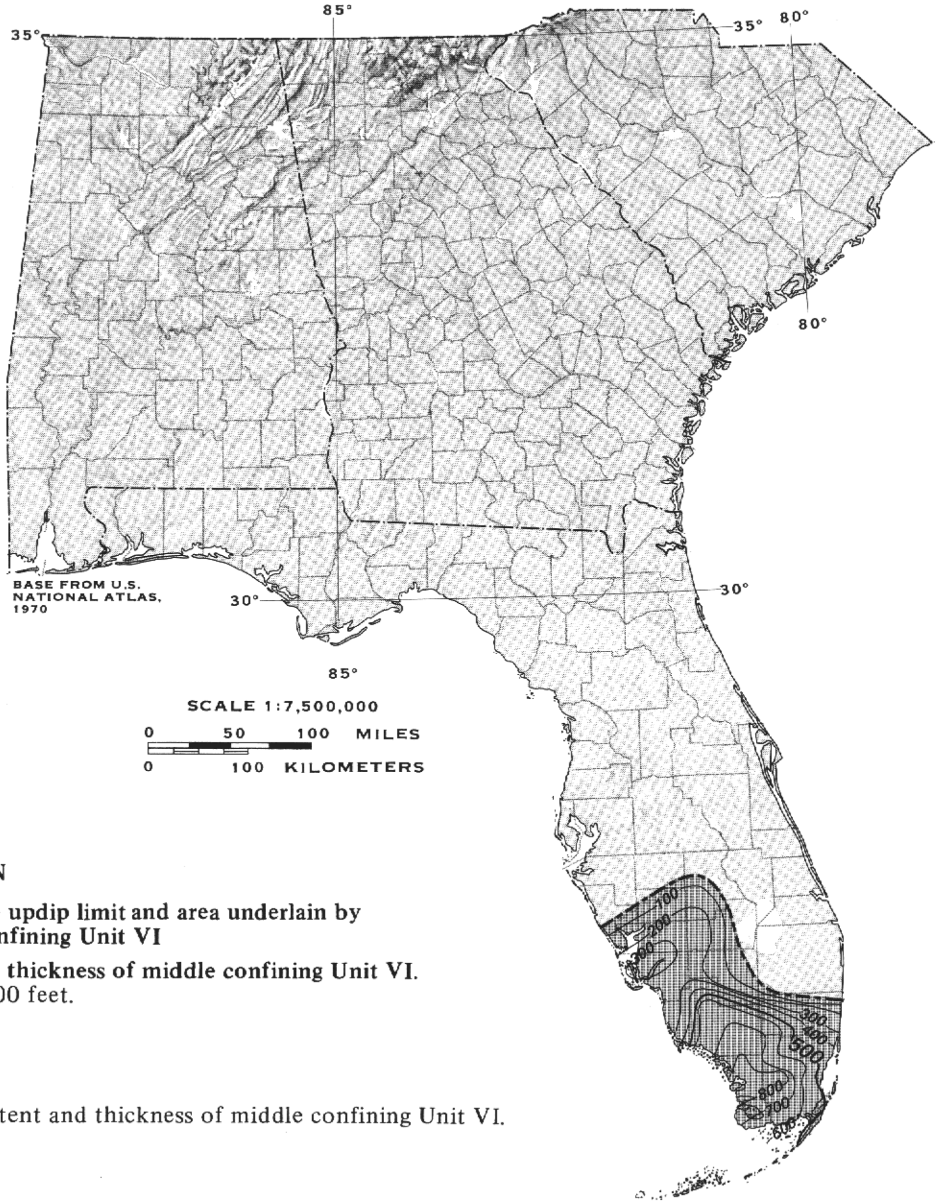
Approximate updip limit and area underlain by middle confining Unit VI

—*-2000*— **Structure contour.** Shows altitude of top of middle confining Unit VI. Interval 100 feet. Datum is sea level.

Figure 19. Extent and configuration of the top of middle confining Unit VI.

it is in southern Florida, where it consists of a thick sequence of largely low-permeability rocks separated by relatively thin permeable zones (fig. 21)). For the most part, the rocks comprising the Lower Floridan range from late Paleocene to early middle Eocene age (fig. 9); locally, however, the aquifer may include rocks as young as late Eocene or as old as Late Cretaceous. Some of the thick low- and high-permeability subzones within the Lower Floridan are of subregional extent and have been mapped as a part of this study. These subzones are of interest partly because they represent potential waste-storage receiving or confining beds (southern Florida) and partly because they are in places (for example, extreme northeastern Florida and southeastern Georgia) the source of brackish or saline water that has moved upward and contaminated shallower freshwater-bearing strata (Krause and Randolph, 1985).

A subzone of rocks exhibiting extremely high transmissivity lies deep within the Lower Floridan aquifer in southern Florida. These rocks are mostly massively bedded dolomite within which cavernous permeability is extensively developed. The cavernous and in places fractured nature of the dolomite commonly causes chunks of dolomite to be dislodged during the drilling process, and circulation of drilling fluid is usually lost because of the large-scale porosity and high permeability of the dolomite. The difficult, slow drilling of the dolomite is expressed as a rough bit action, similar to that which occurs in the drilling of boulders. This



EXPLANATION

Approximate updip limit and area underlain by middle confining Unit VI

—*500*— **Line of equal thickness of middle confining Unit VI.** Interval 100 feet.

Figure 20. Extent and thickness of middle confining Unit VI.

behavior gave rise to the term "Boulder Zone," first applied to the cavernous dolomite by drillers and subsequently adopted by Kohout (1965) and later authors. The term Boulder Zone is a misnomer because no boulders are present (other than the large chunks occasionally broken off cavern roofs by the drill bit), and the cavernous dolomite is not confined to a single discrete zone. Thus, a "boulder zone" has no stratigraphic significance, because such cavernous conditions can exist at any altitude. The large solution features merely record a period when paleowater tables were at a level that permitted karstification of the upper part of the carbonate rock sequence. Once developed, the karst features can be buried at considerable depth, as they have been in southern Florida's Boulder Zone.

A "boulder zone" does not represent a single cavernous horizon developed over a wide area at the same depth or at the same stratigraphic position. Rather, such a zone represents a fairly thick horizon of large-scale solution-produced openings that are developed, like modern cave systems, primarily parallel to bedding planes at several different levels over a vertical span that may reach several hundred feet. Borehole televiewer surveys show that these levels, separated by intervals of undissolved rock, are commonly connected by vertical fractures. If these fractures are enlarged by dissolution, vertical "pipes" are developed

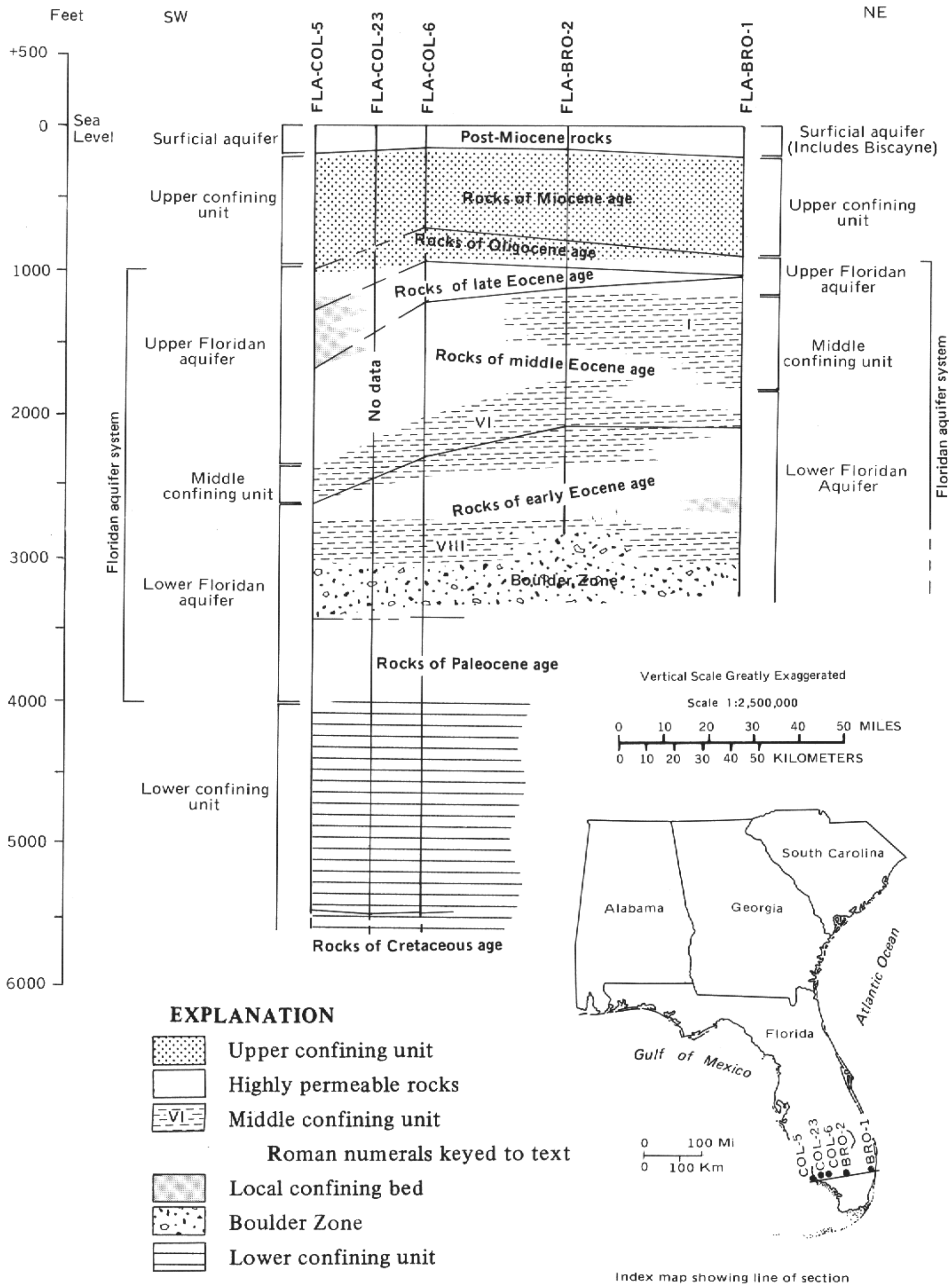


Figure 21. Generalized geohydrologic cross section from western Collier to eastern Broward Counties, Fla.

that connect the horizontal cavernous levels. The 90-ft- high "cavern" reported by Kohout (1965, p. 262) in his discussion of the Boulder Zone is thought by this author to represent such a pipe rather than a large "room" in a cavern system.

Even though a "boulder zone" is not everywhere laterally continuous and may extend vertically across stratigraphic horizons, the zone can be used hydrologically in an informal "operational unit" sense. For example, in southern Florida, one can reasonably ex-

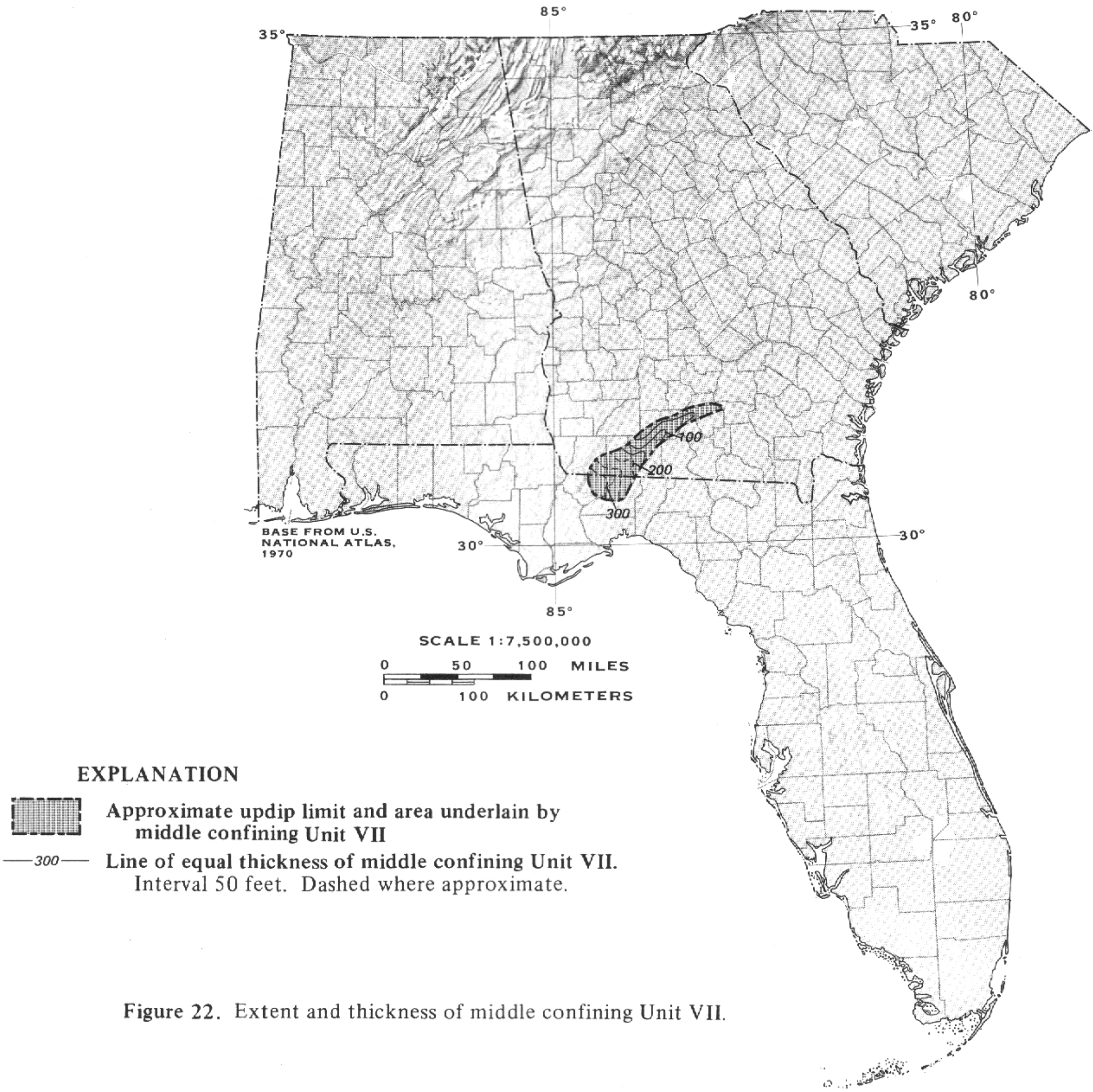


Figure 22. Extent and thickness of middle confining Unit VII.

pect to encounter a high-permeability, commonly cavernous zone at depths of about 2,500 to 3,000 ft. The Boulder Zone of the literature (Kohout, 1965) usually occurs in the bottom third of the lower Eocene Oldsmar Formation, about 100 to 150 ft above the top of Paleocene rocks. Locally, the Boulder Zone may range upward to the middle of the Oldsmar or downward to the top of the Paleocene Cedar Keys Formation. In this report, the Boulder Zone is considered to be a widespread high-permeability unit, and the extent and configuration of the top of the zone are shown in figure 23. The Boulder Zone loses its cavernous character northward and merges with permeable strata that are part of the Lower Floridan aquifer (see pls. 17, 30). Temperature and salinity data from Boulder Zone waters, supplemented by scattered hydraulic head data, indicate that the Boulder Zone is connected to the modern ocean in the Straits of Florida and that there is inland flow of water in the zone (F. W. Meyer, written commun., 1984). The permeability of the Boulder Zone is extremely high owing to its cavernous nature. An analysis of cyclic natural water-level fluctuations in a partially penetrating well (Meyer, 1974) yielded a transmissivity of 3.2×10^6 ft^2/d for only the upper 20 ft of the zone. The transmissivity of the entire thickness of the Boulder Zone probably exceeds 10^7 ft^2/d. The Boulder Zone contains saline water everywhere and is extensively used along Florida's southeastern coast as a receiving zone for treated municipal liquid wastes.

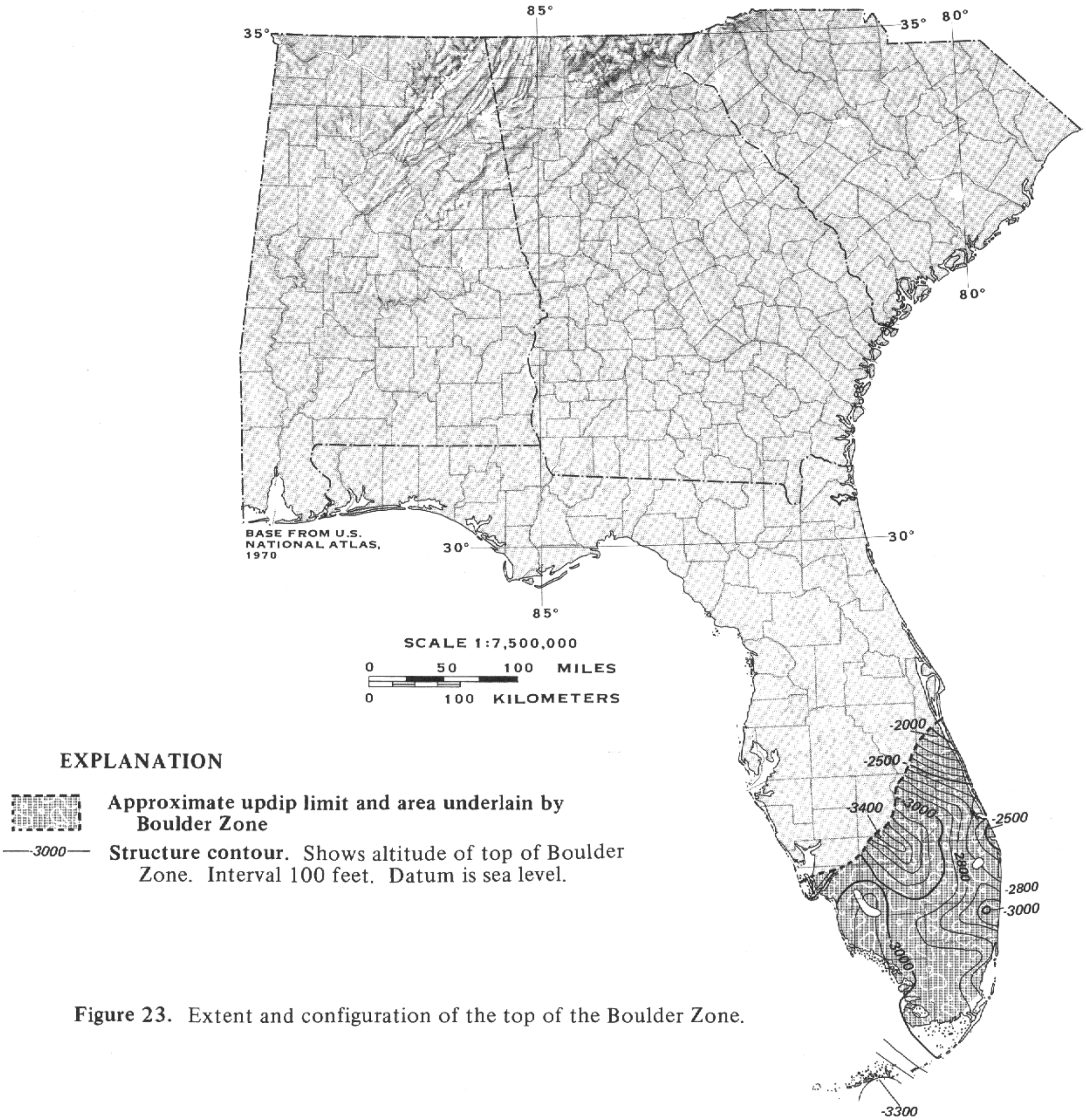


Figure 23. Extent and configuration of the top of the Boulder Zone.

A second high-permeability zone that is cavernous in part lies above the Boulder Zone and occurs in the lower part of rocks of middle Eocene age. In general, this shallower zone is found north of the Boulder Zone and in places overlaps it (Miller, 1979). Unlike the Boulder Zone, the middle Eocene cavernous interval commonly contains freshwater. Locally, as many as eight separate cavernous levels have been penetrated in the same borehole (Vernon, 1970, p. 10). Only the middle Eocene cavernous interval and the Boulder Zone are areally extensive, however, and only the Boulder Zone has been mapped for this study; the middle Eocene cavernous interval is not separated from the other permeable strata in the Lower Floridan aquifer. Neither cavernous zone appears to be consistently related to rock type or texture, dolomite percentage, thickness of the stratigraphic unit containing the zone, or location of chert, anhydrite, or peat beds. The shallower cavernous interval shows high permeability where middle Eocene rocks are structurally high, as one would expect if the zone were produced by karst activity. The Boulder Zone, however, shows no such relationship.

A thick middle confining unit that is regionally included in the Lower Floridan aquifer overlies and extends beyond the Boulder Zone (pls. 17, 30). This unit occurs in the middle part of rocks of early Eocene age and consists mostly of micritic to finely pelletal limestone and lesser amounts of interbedded, finely crystalline dolomite. The extent and configuration of

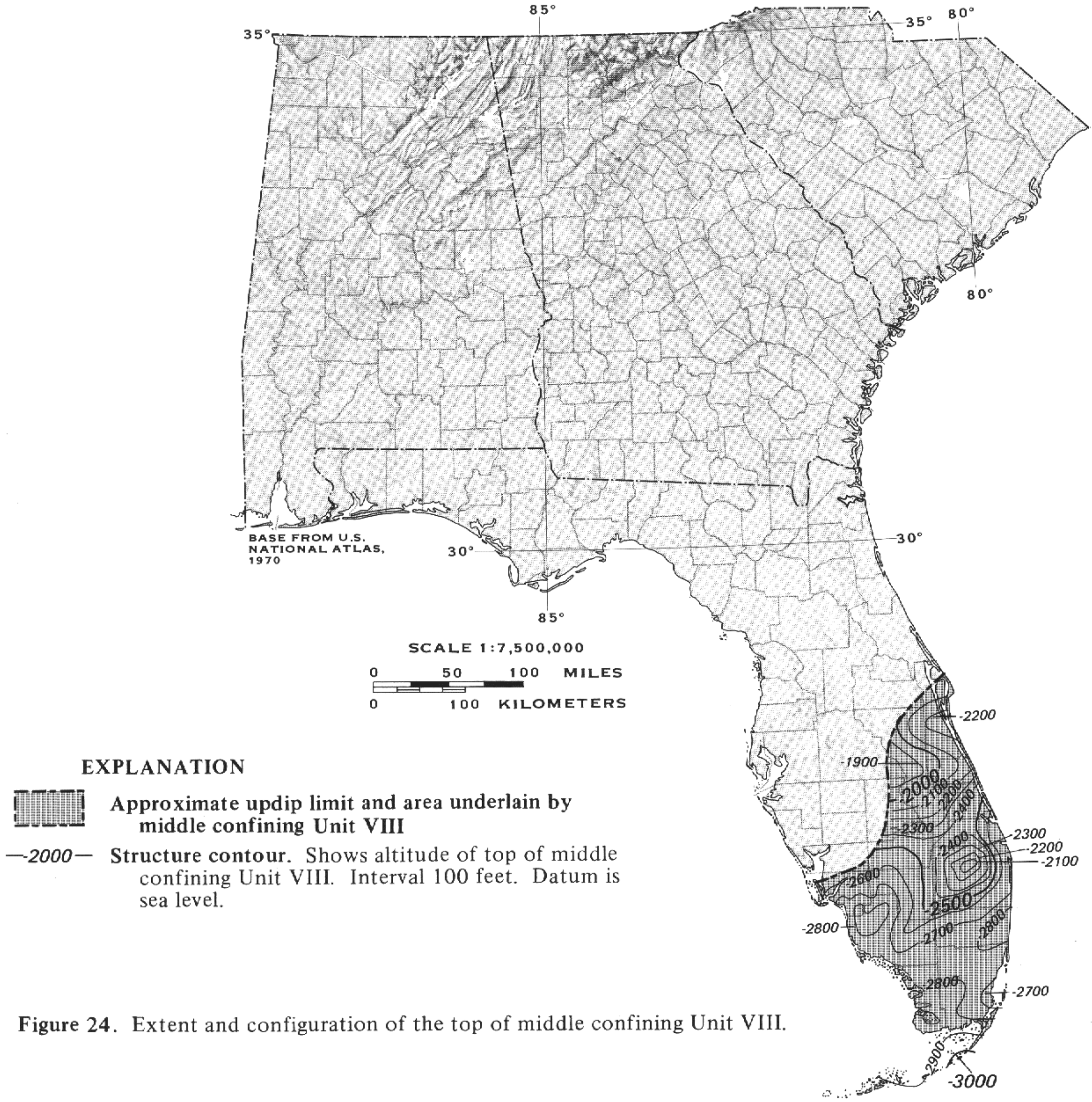


Figure 24. Extent and configuration of the top of middle confining Unit VIII.

the top of this confining unit are shown in figure 24. The unit is designated middle confining unit VIII, and its relation to the Boulder Zone is shown on plate 30. The thickness of the unit is shown in figure 25. Test drilling done for this study shows that thin local beds of dolomite within this confining unit have high permeability, but the overall permeability of unit VIII is low. Data from several deep test and injection wells along Florida's southeastern coast, some areas of which use the Boulder Zone as a receiving zone for treated municipal liquid wastes, show that unit VIII is an effective confining unit there.

Little is known about unit VIII in southwestern Florida, but scattered data from oil test wells indicate that it is an effective confining unit. To the north and west, unit VIII grades laterally into permeable beds that are part of the Lower Floridan aquifer (pl. 17).

A high-permeability unit of subregional extent lies at the base of the Lower Floridan aquifer in parts of southeastern Georgia and northeastern Florida. This unit is given the informal designation "Fernandina permeable zone" in this report because it is best known in the Fernandina Beach area of easternmost Duval County, Fla. The extent and configuration of the top of the Fernandina permeable zone are shown in figure 26. The zone consists of coarsely pelletal, vuggy limestone that is commonly dolomitized and locally cavernous in its upper part. For the most part, the zone is

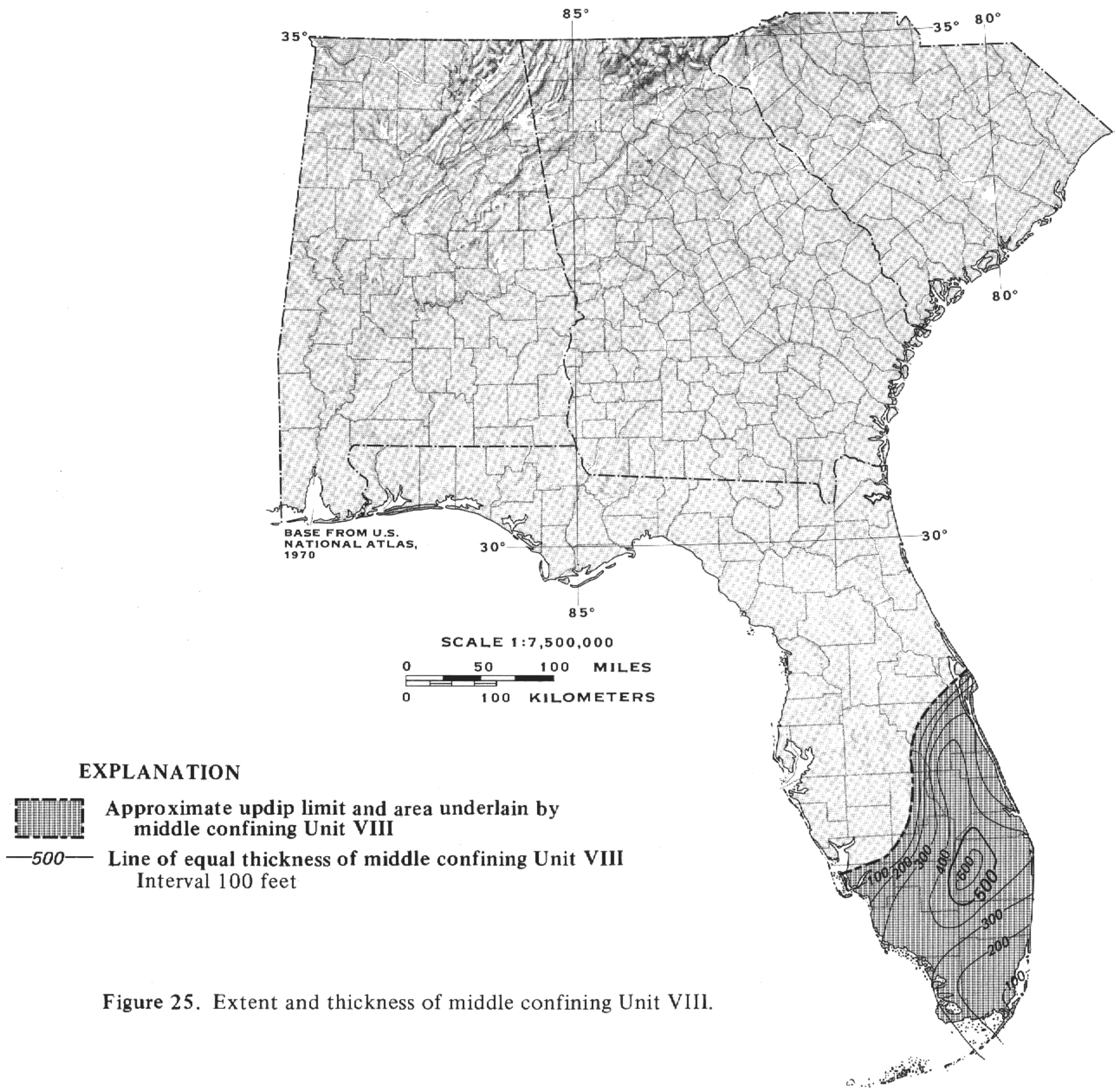
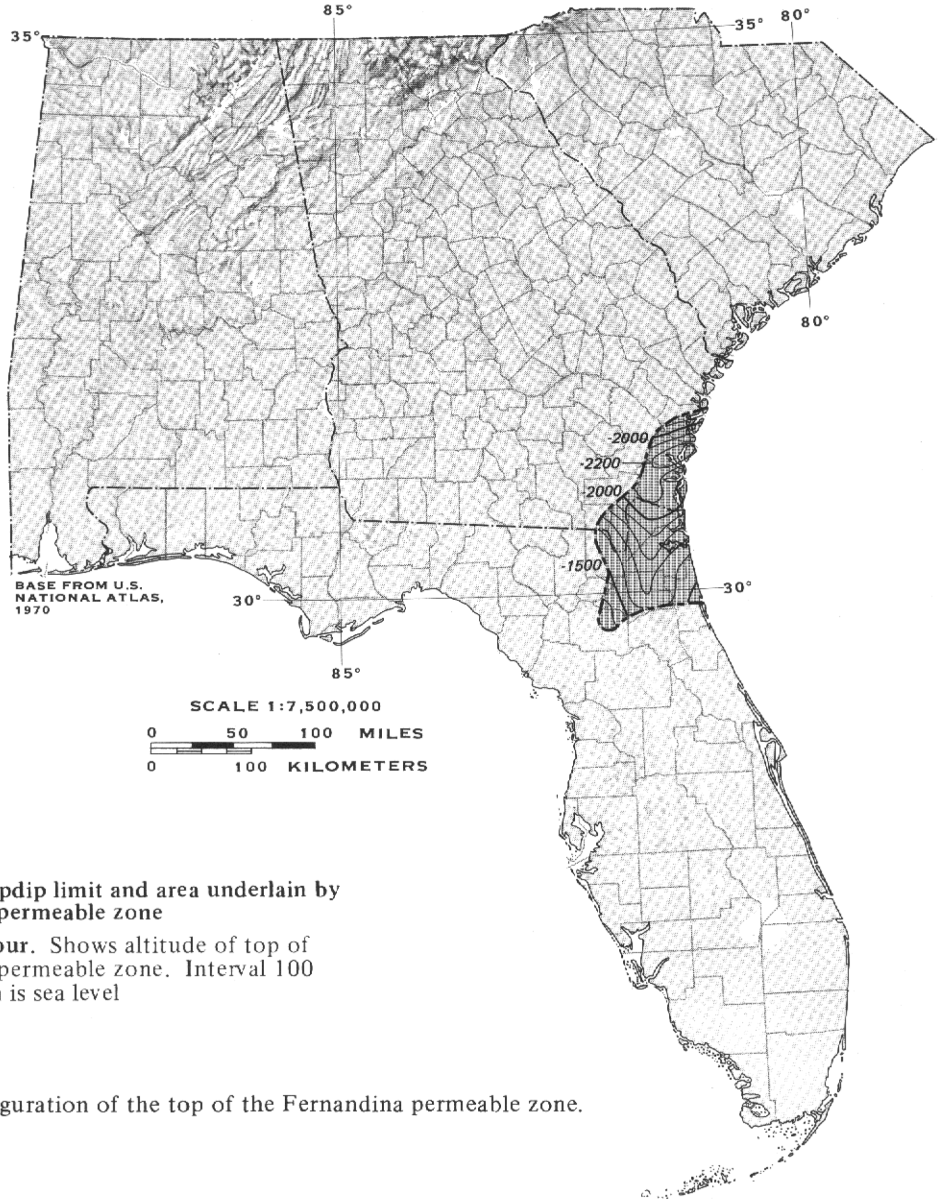


Figure 25. Extent and thickness of middle confining Unit VIII.

restricted to rocks of late Paleocene age, but in places it includes rocks as young as early Eocene or as old as Late Cretaceous (fig. 12). The Fernandina permeable zone is overlain by a confining unit composed of microcrystalline, locally gypsiferous dolomite and finely pelletal micritic limestone that in most places effectively separates the zone from shallower permeable strata. In the Brunswick, Ga., area, however, unpublished data from a deep test well (H. E. Gill, oral commun., 1982) show that this confining unit is fractured and that the fractures provide conduits that have allowed saline water from the Fernandina permeable zone to move upward in response to heavy pumping from the Upper Floridan aquifer and thereby contaminate the shallower permeable zones. The confining unit pinches out in Florida to the south and southwest, and the Fernandina zone merges with shallower permeable strata (fig. 12). To the north and west in Georgia, the confining unit is shown in figure 12 to be a tongue of low-permeability material that extends downdip into permeable strata from the aquifer's lower confining unit. Locally, water in the uppermost part of the Fernandina permeable zone is fresh (Leve and Goolsby, 1967; Brown, 1980), but the high salinity of the water that the zone contains in most places shows that ground-water flow in the zone is very sluggish. Simulation (Krause and Randolph, 1985) shows that the Fernandina zone is part of the Floridan aquifer



EXPLANATION

Approximate updip limit and area underlain by Fernandina permeable zone

—·1500— **Structure contour.** Shows altitude of top of Fernandina permeable zone. Interval 100 feet. Datum is sea level

Figure 26. Extent and configuration of the top of the Fernandina permeable zone.

system's regional flow network, however. Although the Fernandina zone is locally cavernous, it is in no way connected with or related to south Florida's Boulder Zone. The Fernandina permeable zone is included as a subunit of the Lower Floridan aquifer (fig. 8).

LOWER CONFINING UNIT

The rocks that comprise the Floridan aquifer system's lower confining unit are generally of two types: either glauconitic, calcareous, argillaceous to arenaceous strata that range in age from late Eocene to late Paleocene or massively bedded anhydrite that usually occurs in the lower two-thirds of rocks of Paleocene age. Locally, in the Mobile Graben and just to the northwest of it in western Alabama, the Lower Floridan aquifer is not present, and the Bucatunna Formation that comprises middle confining unit V elsewhere forms the base of the aquifer system. The permeability of the rocks comprising the aquifer system's base is everywhere much less than that of the carbonate rocks that lie above them. Like the top of the aquifer system, its base is defined in terms of a permeability contrast and does not conform to the same geologic horizon or rock type everywhere. The altitude and configuration of the base of the aquifer system (top of its lower confining unit) as shown on plate 33, modified from a map by Miller (1982c), thus represent a composite surface that crosses formation